VASQUEZ-BEGGS

The Vasquez-Beggs equation (VBE) is the easiest calculation tool to use. It is most appropriate for use on upstream operations, such as stock tanks at wellheads, oil and gas production batteries, and for "black oil" (a heavy, low-volatility oil approximated by a gas to oil ratio of less than 1750 cubic feet and API gravity less than 40 degrees). It is the default method required by KDHE for all facilities with flash emissions. This model only has eight input variables: API gravity, separator pressure (psig), temperature (ºF), gas specific gravity, volume of produced hydrocarbons (bbls/day), molecular weight of the gas, VOC fraction of the emissions, and atmospheric pressure (psia). An example is attached (see attachment 1).

With the VBE, tank-flashing losses are calculated as total VOC's (only) and are not speciated into individual chemical compounds or HAPs. It has been shown that tank-flashing estimates of VOCs using the VBE may be considerably underestimated or overestimated, depending on the numerous variables that affect flash losses. The variability is more apparent when modeling tank-flashing near the wellhead, where the pressure drop is highest and liquid composition is more variable. The VBE model does not calculate standing or working losses from storage tanks.

HAP-Calc using VASQUEZ-BEGGS

The HAP-Calc model uses the Vasquez-Beggs method to estimate VOC tank-flashing emissions, so KDHE will accept this analysis instead of spreadsheet calculations. In addition to estimating VOC tank-flashing emissions, the HAP-Calc program speciates HAP emissions. The HAP emissions can be estimated by entering site-specific data, or by using default program values. The HAP-Calc program runs in Windows format and costs about $75 through the Gas Research Institute (GRI). Since it uses Vasquez-Beggs as the basis for its calculations, this program may err in the same way compared to process simulators.

ENVIRONMENTAL CONSULTANTS and RESEARCH, Inc.

Environmental Consultants and Research, Inc. equation (EC/R) estimates the ratio of each component in the liquid phase versus the vapor based on the tank pressure and the mole fraction of the vapor flashed. The flash emissions from the tank are then calculated using that information, the tank throughput, the density of the hydrocarbon liquids, and the mass fraction of each component in the liquid. At pressures below 1.6 atm (~8.8 psig), emissions are assumed to approach zero and at pressures greater the 5.1 atm (~60.3 psig), another emission estimation is required. An example is attached (see attachment 2).

E&P TANKS

In addition to tank-flashing losses, the E&P Tanks program estimates tank working and standing losses. The model uses the Peng-Robinson equation of state to estimate tank-flashing losses and speciates between HAP emissions and VOCs. This model is best suited for upstream operations, such as stock tanks at wellheads and tank batteries common to several wellheads, although it will handle a broader range of API gravities (15-68).

The program costs about $300 (in 2002) from the American Petroleum Institute (API) and tends to be more complicated than Vasquez-Beggs to run. Even though this model uses the Peng-Robinson equation of state, evaluations compared with process simulators give somewhat inconsistent results with variations in pressure inputs. It has been shown that the E&P Tanks model may also underestimate or overestimate VOC tank-flashing emissions, but not as much as the Vasquez-Beggs equations.

DETERMINATION of the GAS OIL RATIO

Determination of the hydrocarbon liquid gas oil ratio (GOR) can be obtained by collecting a pressurized sample upstream of the storage tank (i.e. separator dump line). The flashing losses/emissions can be determined by multiplying the GOR by the throughput of the tank. An extended hydrocarbon analysis of the flash gas from the sample should also be conducted to identify the concentrations of the individual components of the tank's flash emissions.

PROCESS SIMULATORS

Process simulators are computer models that use EOS and mass energy balances to simulate petroleum processes for a variety of engineering purposes. There are several different manufacturers of process simulators (HYSIM, HYSIS, WINSIM, PROSIM, etc.) each utilizing similar basic principles. Process simulators are mainly used in process design and have been demonstrated to accurately predict natural gas and petroleum processes. Process simulators can be used to estimate flash emissions and speciate these emissions. Required inputs may include an extended pressurized condensate analysis as well as other parameters (e.g. temperature, pressure, and flow) for the process being simulated. Process simulators are not constrained by API gravity. This method pf estimating potential flash emissions can be very expensive ($13,000 a year to own) and complicated and is expected to be more accurate when estimating flashing losses/VOC emissions from hydrocarbon storage tanks than other emissions estimation methods.

DIRECT MEASUREMENT of EMISSIONS

Actual testing of emissions from the tanks also can be performed to determine flash emissions. Since, there are no currently approved U.S. EPA reference methods that are developed specifically fro measuring emissions from storage tanks, approved reference methods and modified reference methods or other approved methods may be used to characterize and determine these emissions, with prior approval from KDHE. However, it should be noted that such testing is just a snapshot of the emissions and should be used in conjunction with a safety factor to establish emission limits.

Note: The following table shows values that have been accepted as default values for VBE calculations:

Inputs	Units	Default Value
Stock Tank API Gravity	API	78.0
Separator Temperature	ºF	60.0
Separator Gas Specific Gravity		0.9
Stock Tank Gas Molecular Weight	lb/lb-mole	49.0
VOC Fraction of the Stock Tank Gas	Fraction	0.8
Atmospheric Pressure	psia	14.7

Other values may be used as long as they have been obtained from site-specific data collection or are based on a representative sample.

The referenced method summaries are from New Mexico and Oklahoma. Attachments 1 and 2 for example calculations can be found on the Oklahoma website http://www.deq.state.ok.us/AQDnew/resources/Calculations11.xls.

Company Name:		Permit No.:	
Facility Name:		Date:	

Volatile Organic Compound Emission Calculation for Flashing

Vasquez - Beggs Solution Gas/Oil Ratio Correlation Method

(For Estimating VOC Flashing Emissions, Using Stock Tank Gas-Oil Ratios For Crude Oil Facilities)

INPUTS:

Stock Tank API Gravity	78	API
Separator Pressure (psig)	33	P
Separator Temperature (°F)	60	Ti
Separator Gas Gravity at Initail Condition	0.9	SGi
Stock Tank Barrels of Oil per day (BOPD)	19.3	Q
Stock Tank Gas Molecular Weight	49	MW
Fraction VOC (C3+) of Stock Tank Gas	0.8	VOC
Atmospheric Pressure (psia)	14.7	Patm

CONSTRAINTS:

16	>API>	58	°API	WARNING ....
50	>P+Patm>	5250	(psia)	WARNING ....
70	> Ti >	295	(°F)	WARNING ....
0.56	>SGi>	1.18	MW/28.97	ok
None	> Q >	None	(BOPD)	ok
18	>MW>	125	lb/lb-mole	ok
0.5	>Voc>	1.00	Fraction	ok
20	> Rs >	2070	(scf/STB)	ok

SGx = Dissolved gas gravity at 100 psig = SGi [1.0+0.00005912*API*Ti*Log(Pi/114.7)]

SGx =	0.81

Document Notes:

Rs = (C1 * SGx * Pi^C2) exp ((C3 * API) / (Ti + 460))

Where:

Rs	Gas/Oil Ratio of liquid at pressure of interest
SGx	Dissolved gas gravity at 100 psig
Pi	Pressure of initial condition (psia)
API	API Gravity of liquid hydrocarbon at final condition
Ti	Temperature of initial condition (F)

Constants

	°API Gravity		
°APTI →	< 30	>= 30	Given °API
C1	~~0.0362~~	0.0178	0.0178
C2	~~1.0937~~	1.187	1.187
C3	~~25.724~~	23.931	23.931

Rs =	51.01	scf/bbl	*for P + Patm =*	*47.7*

THC = Rs * Q * MW * 1/385 scf/lb-mole * 365 D/Yr * 1 ton/2000 lb.s

THC	Total Hydrocarbon (tons/year)
Rs	Solution Gas/Oil Ratio (scf/STB)
Q	Oil Production Rate (bbl/day)
MW	Molecular Weight of Stock Tank Gas (lb/lb-mole)
385	Volume of 1 lb-mole of gas at 14.7 psia and 68 F (WAQS&R Std Cond)

THC =	22.9	TPY

VOC = THC * Frac. of C3+ in the Stock Tank Vapor

VOC =	18.3	TPY	*from "FLASHING" of oil from separator to tank press*

EC/R Algorithm (Akin Battye, 1994)
Tom Atkin & William Battye, 1994. Memorandum to Martha E. Smith, U.S. EPA.
Environmental Consultants and Research, Inc. 10/18/94 Durham, NC

For flashing losses from tanks based on the pressure drop of the process stream.
Derived from the behavior of the liquid stream based on changes in stream compositions and pressure.
Method assumes that the equilibrium of the liquid and vapor are reached at STP and the tank is at STP.
Valid for liquid streams between pressures of 1.64 and 5.10 atmospheres. (23.5 psia to 75 psia)

Pressure of Separator	33.00 psig	MAXIMUM VALUE	61 psig
Throughput of Condensate	19.30 bbl/day		
Specific Gravity of Condensate	78.00 API	DEFAULT VALUES	78 API
Vapor Pressure of Condensate	7.48 psia	DEFAULT VALUES	8 psia

Flashing Losses/Emissions	4.07 lb/hr 17.84 TPY

If the composition of the liquid coming from the separator are known enter here for a more comprehensive emission breakdown.

Mole Fraction		MW		Mass Fraction
X_{N2}	0.000	28.0	0.0	0.000
X_{CO2}	0.001	44.0	0.1	0.001
X_{C1}	0.024	16.0	0.4	0.004
X_{C2}	0.019	30.1	0.6	0.006
X_{C3}	0.055	44.1	2.4	0.026
X_{nC4}	0.045	58.1	2.6	0.028
X_{iC4}	0.015	58.1	0.9	0.010
X_{nC5}	0.038	72.1	2.7	0.029
X_{iC5}	0.034	72.1	2.4	0.026
X_{C6}	0.081	84.2	6.8	0.073
X_{C7}	0.229	100.2	23.0	0.244
X_{C8}	0.287	114.2	32.8	0.348
X_{C9+}	0.070	142.3	10.0	0.106
HAPs				
$X_{Benzene}$	0.003	78.1	0.3	0.003
$X_{Toluene}$	0.028	92.1	2.6	0.028
$X_{EthylBenzene}$	0.000	106.2	0.0	0.000
X_{Xylene}	0.032	106.2	3.4	0.036
$X_{n\text{-}Hexane}$	0.035	86.2	3.1	0.032
TOTALS	0.999		94.07	1.00

Flashing losses/emissions

VOC	lb/hr	TPY
E_{C3}	1.26	5.51
E_{C4}	0.49	2.15
E_{C4}	0.25	1.07
E_{C5}	0.17	0.73
E_{C5}	0.20	0.89
E_{C6}	0.09	0.37
E_{C7}	0.15	0.68
E_{C8}	0.07	0.33
E_{C9+}	0.00	0.00
$E_{Benzene}$	0.00	0.01
$E_{Toluene}$	0.00	0.01
$E_{EthylBenzene}$	0.00	0.00
E_{Xylene}	0.00	0.02
$E_{n\text{-}Hexane}$	0.04	0.17
	2.73	11.95